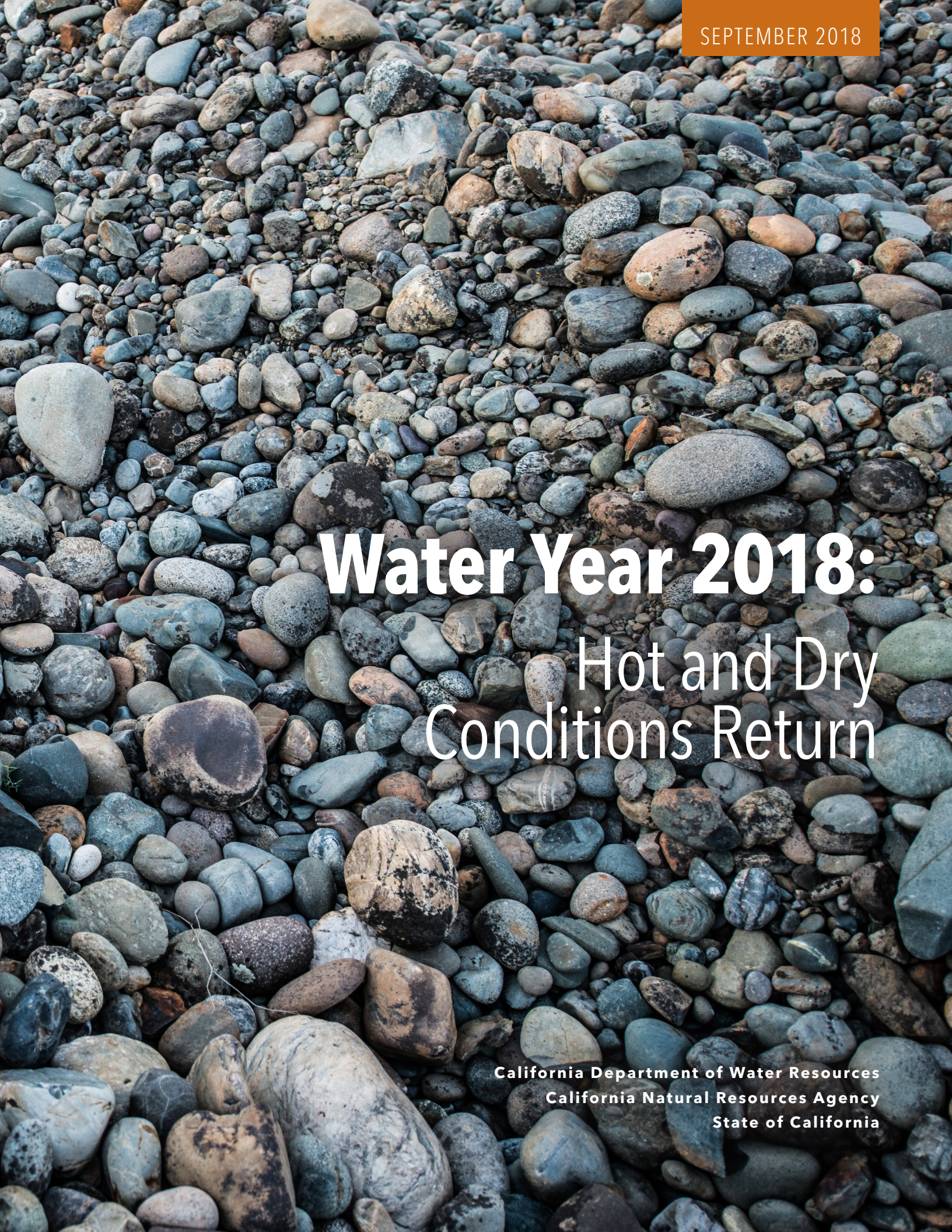


SEPTEMBER 2018

Water Year 2018:
Hot and Dry Conditions Return

California Department of Water Resources
California Natural Resources Agency
State of California

Dry, Hot, and On Fire

Water year 2018 (October 1, 2017, to September 30, 2018) marked a return to dry conditions statewide, with nearly all the state experiencing below-average precipitation and much of Southern California receiving half or less of its average annual precipitation. Water year 2018 followed California's second-wettest year of record as measured by statewide runoff, ending a historic five-year drought.

The year provides another indicator of California's ongoing transition to a warmer climate, evidenced by continued extremes in precipitation variability and record-setting high temperatures such as those recorded in coastal Southern California during the summer heatwave. A warming climate results in more precipitation falling as rain rather than as snow, which contributed to the water year's lackluster statewide snowpack. The 2018 April 1 reading of snowpack was just 58 percent of average, after hitting 163 percent of average on that date in 2017. Just three years prior to that, California experienced a record-low statewide snowpack of only 5 percent of the April 1 average in 2015.

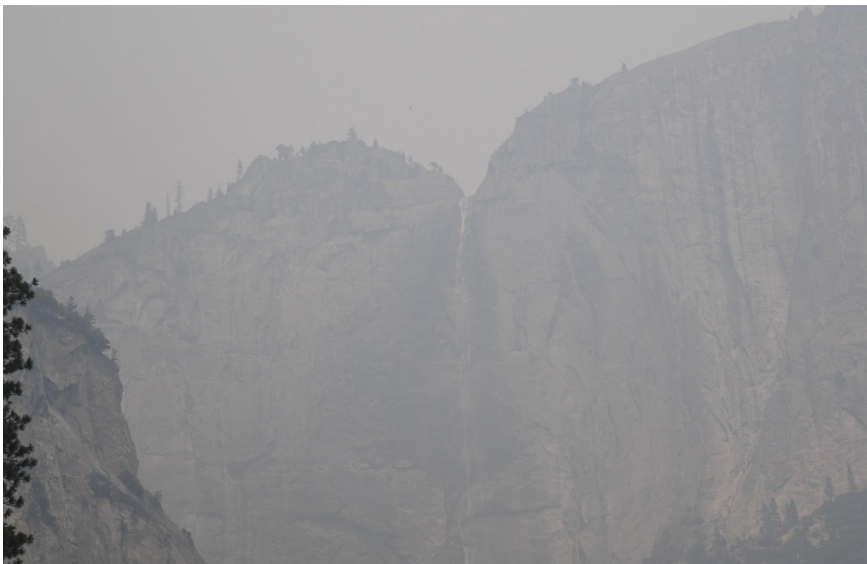
Water year 2018 will probably most be remembered, however, not for its water supply conditions but for new records set for wildfires and wildfire-related damages, including damage to water infrastructure. Increasing wildfire risk and longer wildfire seasons are another hallmark of a warming climate. The drought years of 2012-16 allowed vegetation across the state to become tinder dry, which was compounded by extreme wet conditions in 2017 that encouraged heavy growth of grasses that became fuel for the massive wildfires over the past year. Record temperatures also intensified the fires.

The year's wildfires in California set records and impacted water systems from the Oregon border to Southern California. The October 2017 Tubbs Fire in Napa, Lake, and Sonoma counties ranked as

Above: *The City of Santa Rosa has been replacing destroyed or damaged water service lines and conducting extensive water quality testing in parts of its distribution system where contaminants from melted plastic pipes were detected. Photo courtesy of Office of Emergency Services.*

Below: *A disappointing result at the first snow survey of the winter season in January 2018 at Phillips Station. The December-February period of Water Year 2018 was the fifth-driest on record for DWR's 8-station precipitation index, a measure of relative wetness in the Sacramento River watershed. Only late-spring atmospheric river storms saved Northern California from the very dry conditions that persisted in Southern California.*

Bottom: *Upper Yosemite Falls. The July 2018 Ferguson Fire in the Yosemite area was only one of several wildfires severely affecting Central Valley air quality during this time. Photo courtesy of U.S. Forest Service.*



California's most destructive fire, according to CAL FIRE, devastating a highly urbanized area and causing extensive damage to municipal water distribution systems. The December Thomas Fire in Ventura and Santa Barbara Counties now ranks as the second-largest wildfire in state history and resulted in boil water orders for residents in Ventura, Santa Paula, and Ojai. The Thomas Fire was followed by a January storm with heavy rainfall in the burned area, triggering massive debris flows in Montecito in which 21 people lost their lives. The largest wildfire in state history, the Mendocino Complex Fire, began in July 2018 and burned more than 700 square miles. Also in July, the Carr Fire in Shasta and Trinity counties – the state's sixth most destructive fire – burned the area surrounding the U.S. Bureau of Reclamation's (USBR's) Keswick Dam and powerplant, and resulted in boil water advisories for residents served by several small community services districts. The July Klamathon Fire in Siskiyou County left a small community without potable water for two months and the July Ferguson Fire near Yosemite National Park closed portions of the park and resulted in a boil water order for the small community of Yosemite West.

In addition to the direct damage caused by the wildfires, the upcoming rainy season poses flooding concerns. As rains hit the slick surface of fire-scarred hillsides, the water gathers force and momentum as it travels downhill, taking mud, debris, and trees with it at an accelerated pace that can cause major destruction, like that seen in Montecito last December. All residents living in or downhill from fire-burned areas should take caution and prepare for the risk of flooding after fires.

Precipitation and Temperature

DWR's eight-station precipitation index, which tracks conditions in the Sacramento

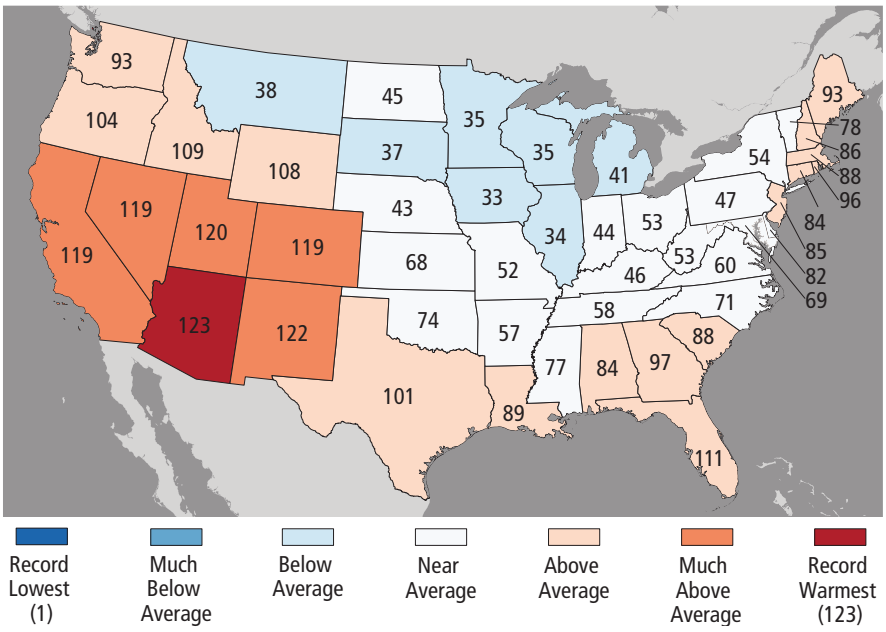
Top: *The Carr Fire largely destroyed the small town of Keswick and resulted in mandatory evacuations of USBR personnel at Keswick Dam and Carr Powerplant (pictured here), Shasta Dam, and the Area Office at Shasta Dam. Photo courtesy of Kathleen Galligan, Detroit Free Press.*

Above: *Boats on USBR's Whiskeytown Lake burned by the Carr Fire. Photo courtesy of USBR.*

Below: *Hornbrook burning. The Klamathon Fire near the California-Oregon border left the small community of Hornbrook without potable water for more than two months after the Hornbrook Community Services District's main water tank was destroyed. Photo courtesy of CHP Yreka.*

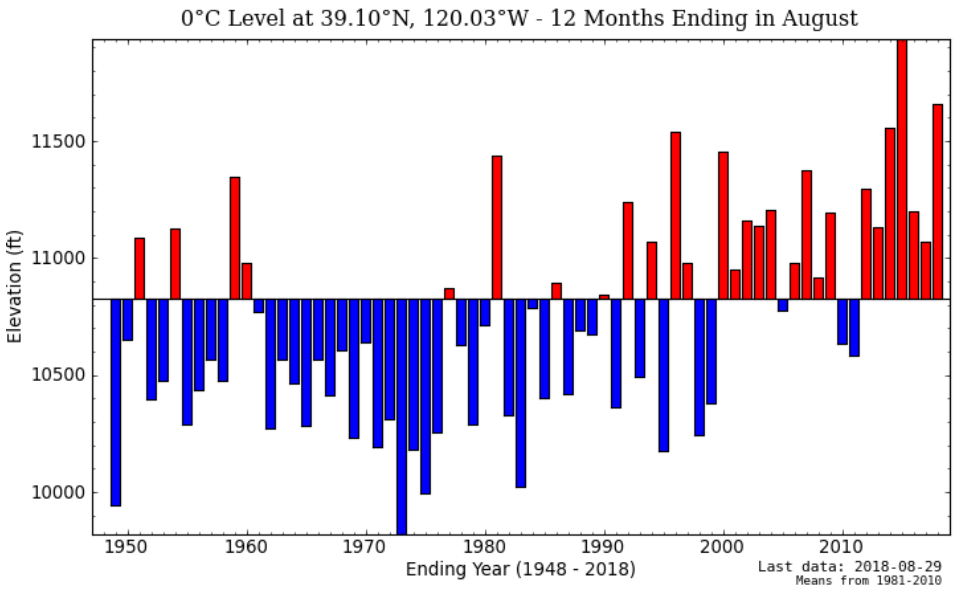
Statewide Average Temperature Ranks (Period: 1895 – 2018)

California once again experienced very warm conditions during the state's wet season November 2017 - April 2018.



Data courtesy of NOAA/ National Centers for Environmental Information (NCEI)

Historical freezing level at Lake Tahoe



Courtesy of Western Regional Climate Center

River Basin watershed, ended the year at 79 percent of average. The five-station San Joaquin precipitation index and the six-station Tulare Basin index wrapped up the year at 74 percent and 62 percent of average, respectively. Statewide snowpack water content was 58 percent of average on April 1, the date historically used to mark peak accumulation. In Southern California, cities such as Los Angeles, Riverside, and San Diego ended the year at 32, 46, and 32 percent of average precipitation, respectively.

Although California experienced fewer major storms in water year 2018 than 2017, several events raised concerns about risks of potential localized flooding and debris flows in burned areas in the North Bay and Santa Barbara areas. Following the devastating Montecito debris flows in January, a forecasted strong atmospheric river storm in March resulted in the precautionary mandatory evacuation of more than 30,000 people in Santa Barbara County, as well as mandatory and voluntary evacuations in Ventura County.

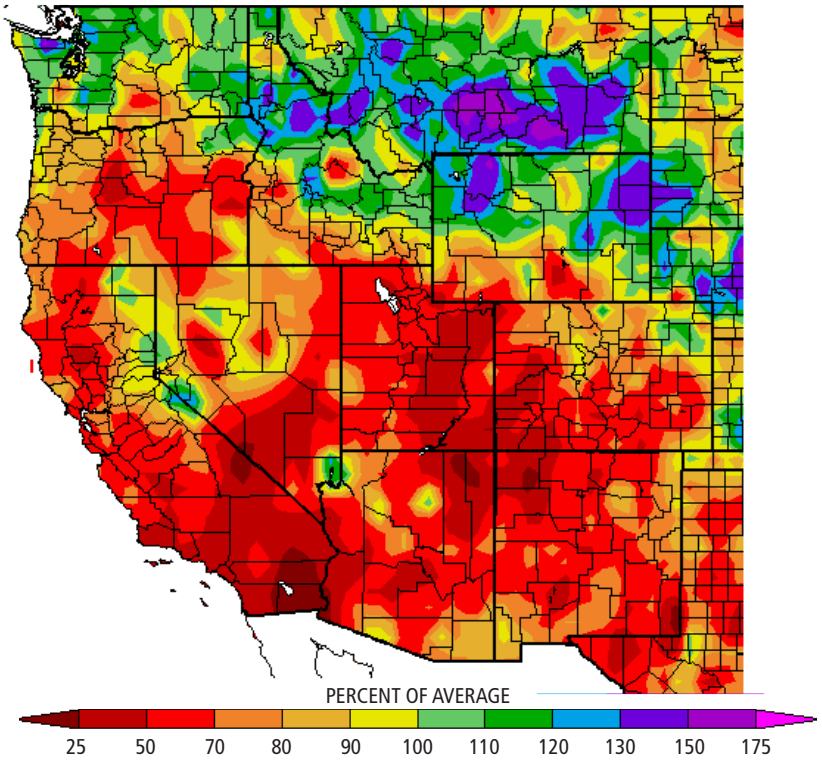
Water year 2018 continued a notable trend of warmer statewide temperatures that began in the 1980s. The summer of 2018, like the summer of 2017, saw new records set for maximum temperatures, especially in the South Coast region. Areas hitting new records during a July heat wave included the University of California, Los Angeles (111 degrees), Burbank (114), Riverside (118), and Chino (120). July 2018 was California's warmest July for statewide average temperatures since recordkeeping began in 1895, according to the National Oceanic and Atmospheric Administration's National Centers for Environmental Information. The monthly average temperature for Death Valley was 108.1 degrees, making it the hottest monthly temperature on record for any station in the world, and surpassing the record previously set there in 2017.

Warming temperatures have many consequences for water supply, including impacts to the percentage of precipitation that falls as rain instead of snow, raising the freezing elevation and shrinking the snow reservoir and snowmelt runoff. As illustrated by the graphs of historical temperature and precipitation for two of California's climate divisions, observed conditions in the 21st century differ from those of the long-term historical record. At Lake Tahoe, warming conditions impact the freezing elevation in the Sierra Nevada with water year 2018 second only to 2015 in the freezing level elevation.

Reservoir and Groundwater Storage

California began water year 2018 with generally good storage conditions in the state's major reservoirs, thanks to a wet water year 2017. Lake Oroville is the exception due to being drawn down for spillway repairs. A significantly dry water year 2018

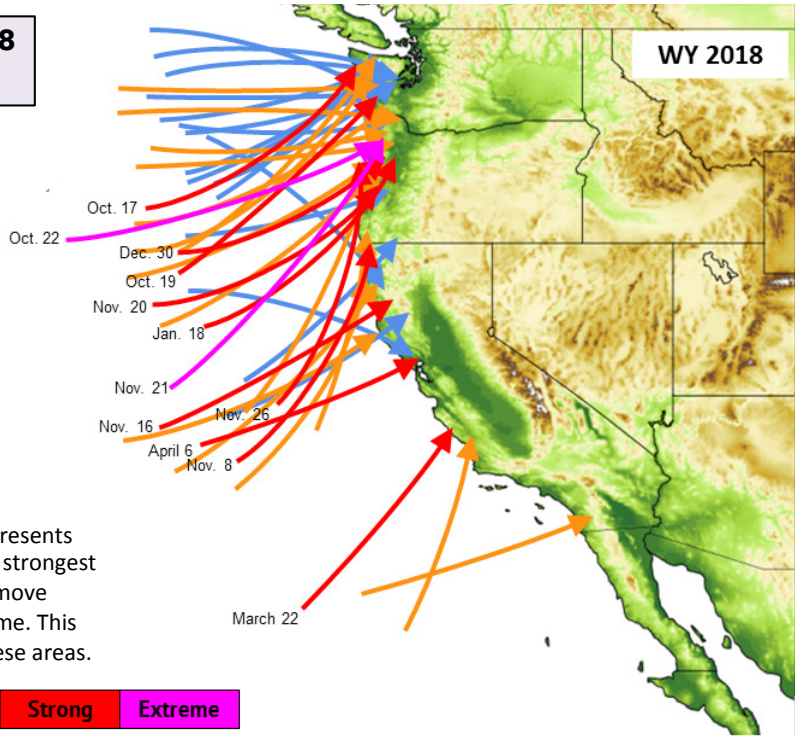
Percent of Average Precipitation, 10/1/2017 - 9/27/2018



Generated 9/28/2018 at Western Regional Climate Center (WRCC) using provisional data. Courtesy of NOAA Climate Centers

Distribution of Landfalling Atmospheric Rivers on the U.S. West Coast (From October 1, 2017, through September 30, 2018)

Water year 2018 AR landfall



Location of landfall represents position where AR was strongest at landfall. Many ARs move down the coast over time. This map does not show these areas.

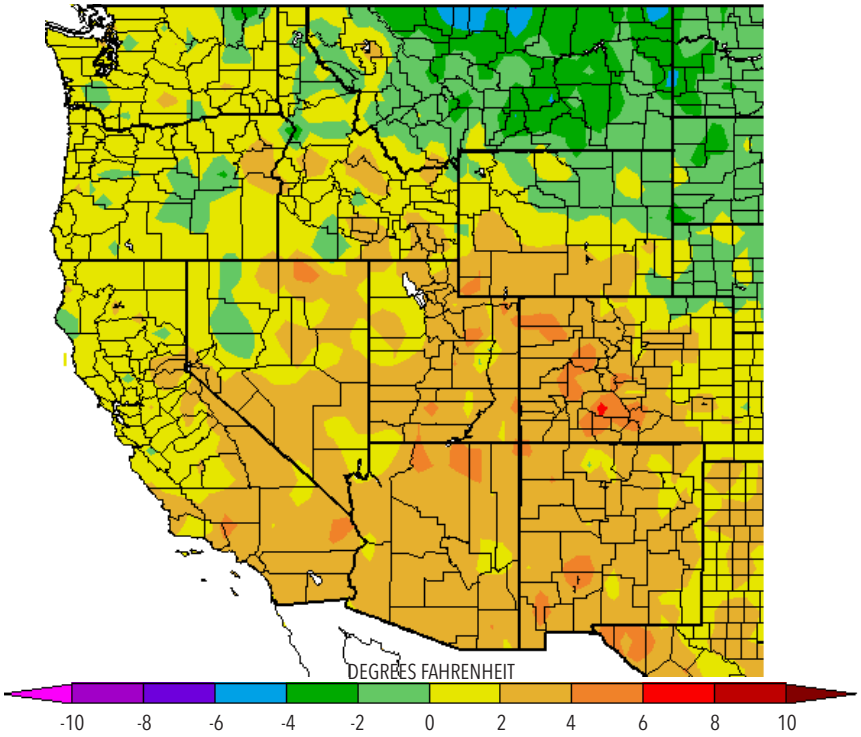
Weak | Moderate | Strong | Extreme

Atmospheric River Strength	Atmospheric River Count*
Weak	16
Moderate	16
Strong	10
Extreme	2

Weak: IVT=250–500 kg m^{-1} s^{-1}
Moderate: IVT=500–750 kg m^{-1} s^{-1}
Strong: IVT=750–1000 kg m^{-1} s^{-1}
Extreme: IVT>1000 kg m^{-1} s^{-1}
IVT = integrated water vapor transport

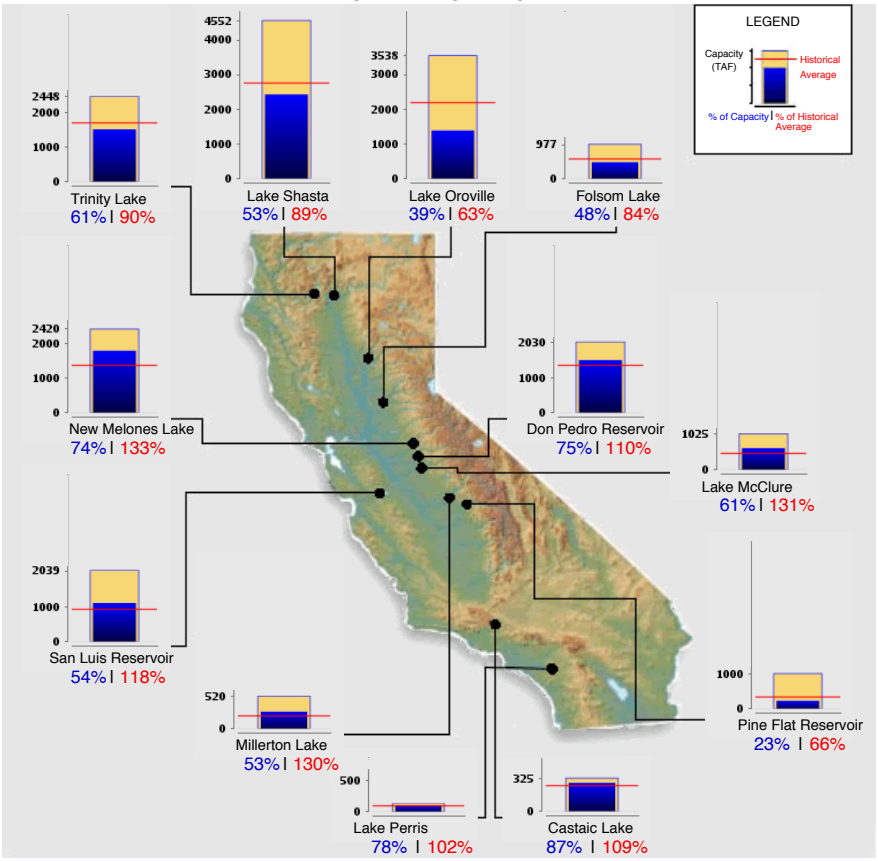
Figure courtesy of Scripps Institution of Oceanography

Average Temperature Departure from Average, 10/1/2017 - 9/27/2018



Generated 9/28/2018 at WRCC using provisional data. Courtesy of NOAA Climate Centers

Current Reservoir Conditions, ending at midnight, September 27, 2018



in Southern California, however, combined with a lack of full drought recovery in some smaller reservoirs resulted in facilities such as Lake Cachuma and Casitas Lake ending the year at less than half of capacity.

Spring 2018 groundwater levels in more than half of California's high-and medium-priority basins, where most of the state's groundwater use occurs, showed little change from Spring 2017 measurements. (Fall 2018 groundwater level information will not be available until the end of the calendar year.) The effects of dominantly dry conditions over the past decade can be seen in the slower recovery of water levels over this longer-term period. Groundwater storage recovers from drought more slowly than does reservoir storage, and deep confined aquifers in severely depleted groundwater basins may show no appreciable recovery because they require a very long time to recharge.

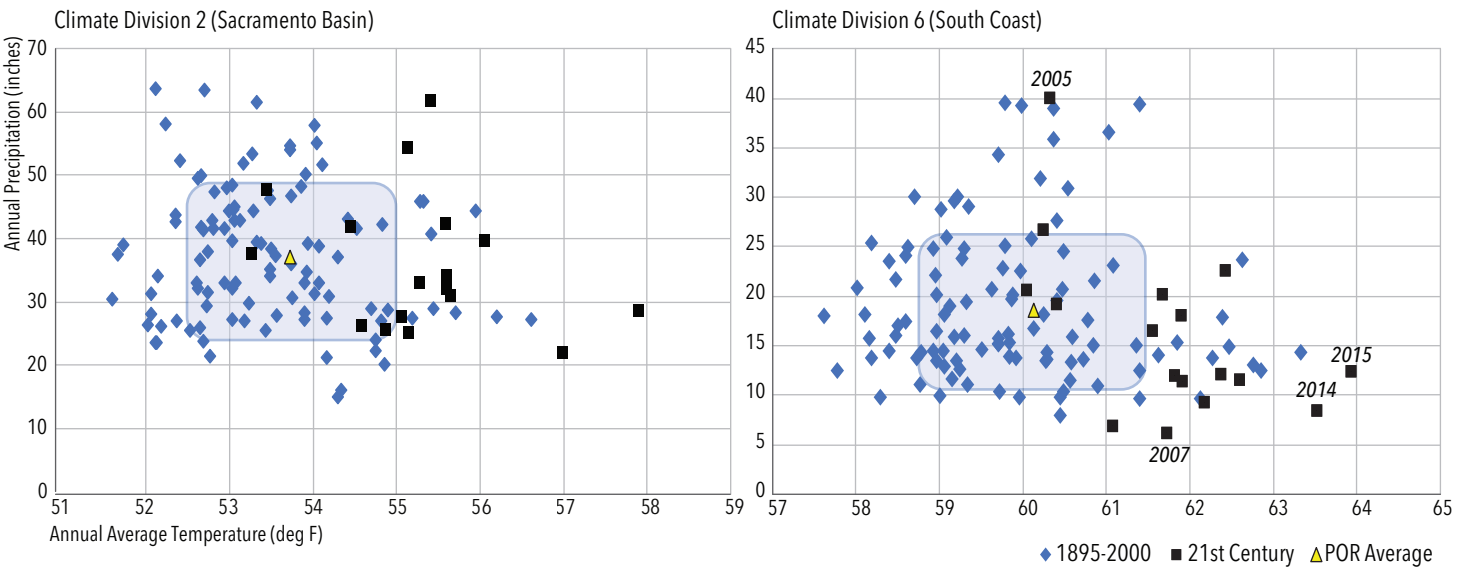
Colorado River Basin

The Colorado River Basin began a prolonged period of generally dry conditions in 2000. Water year 2018 continued this trend, with unregulated inflow into Lake Powell, a key metric of hydrologic conditions, ending the year at 47 percent of the 30-year average. Prolonged dry conditions have taken a toll on the combined storage in Lakes Mead and Powell, which has been fluctuating at half of total capacity in recent years. The risk of a first-ever Lower Basin shortage is increasing. Although no shortage is expected for calendar year 2019 deliveries, prospects of a 2020 shortage are growing.

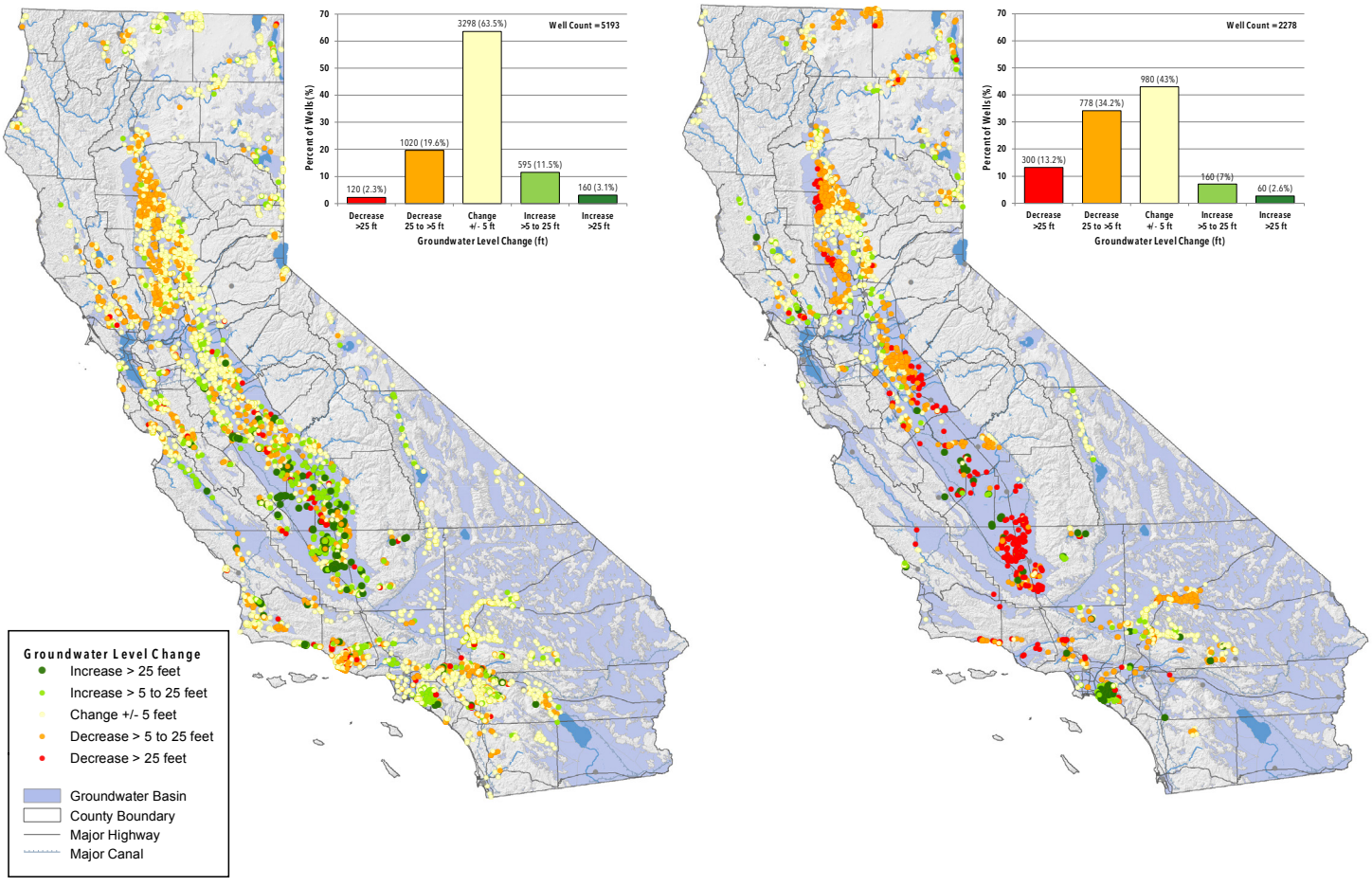
Present operations of Lake Mead and Lake Powell are based on USBR interim guidelines for Lower Basin shortages and coordinated operations of Mead and Powell adopted in 2007 and in effect for operations in calendar years 2008-2025. The guidelines contain provisions for

Comparative Variability of Western Precipitation

Legend: Shaded box represents one standard deviation from mean; POR = period of record



Groundwater Level Changes - Spring 2017 to Spring 2018 (left), Spring 2008 to Spring 2018 (right)



Construction of Southern Nevada Water Authority's (SNWA's) third intake at Lake Mead. The new intake structure is being floated into position via barge, to be lowered to connect to a three-mile, 20-foot diameter tunnel under Lake Mead. The $817 million intake was put into service in 2015, to allow SNWA to ensure water supplies for its customers if lake elevations drop below the level of an existing upper intake. Photo courtesy of SNWA.

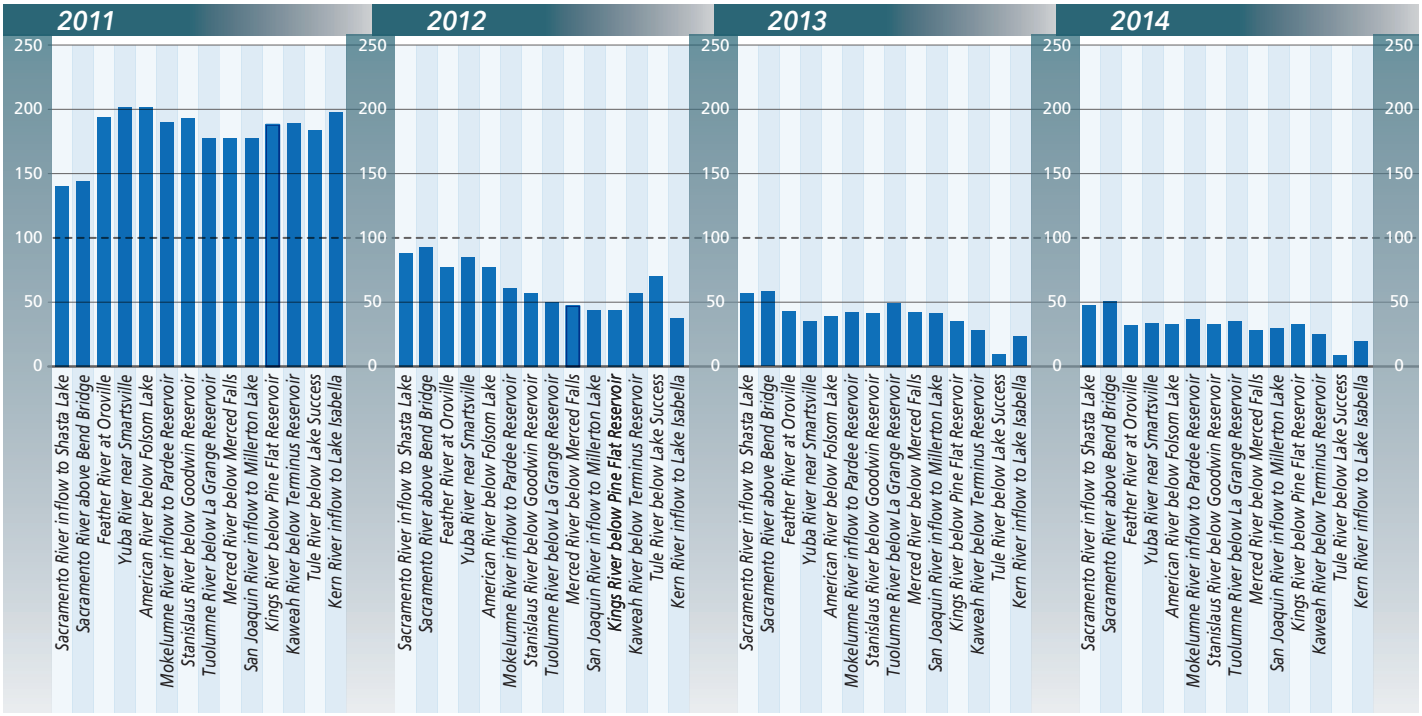
triggering a Lower Basin shortage declaration based on Lake Mead elevations. When the guidelines were negotiated, the prospect of hitting the trigger elevations seemed relatively remote, however. Continued dryness in the basin has increased the likelihood of triggering a shortage. Reclamation's Lower Basin water contractors have been taking actions to avert or prepare for shortage, including a program of extraordinary conservation measures to keep more water in Lake Mead to lessen the risk of hitting a shortage trigger elevation.

Prospects for 2019

Present forecasting capability cannot provide a reliable prediction for water year 2019. Water year 2018 could have been an isolated dry year, or it might mark a return to the multi-year dry conditions of 2012-16, interrupted by a wet 2017. The latter circumstance would be similar to conditions in the Colorado River Basin, where a 19-year period of overall dryness has included an occasional average or wet year.

Predicting the winter's precipitation entails understanding and predicting atmospheric

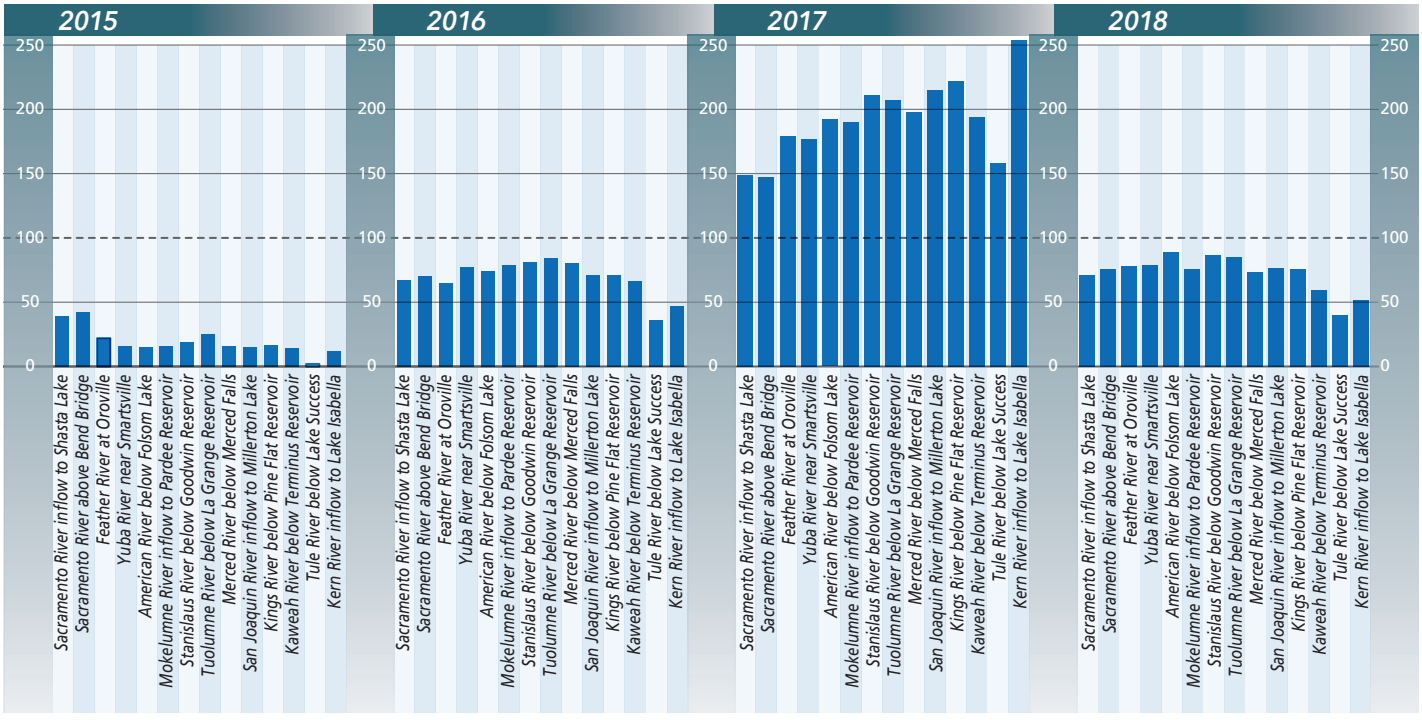
Water year 2011-2018 April-July Runoff at Forecast Points on Major Central Valley Rivers, as Percentage of Average



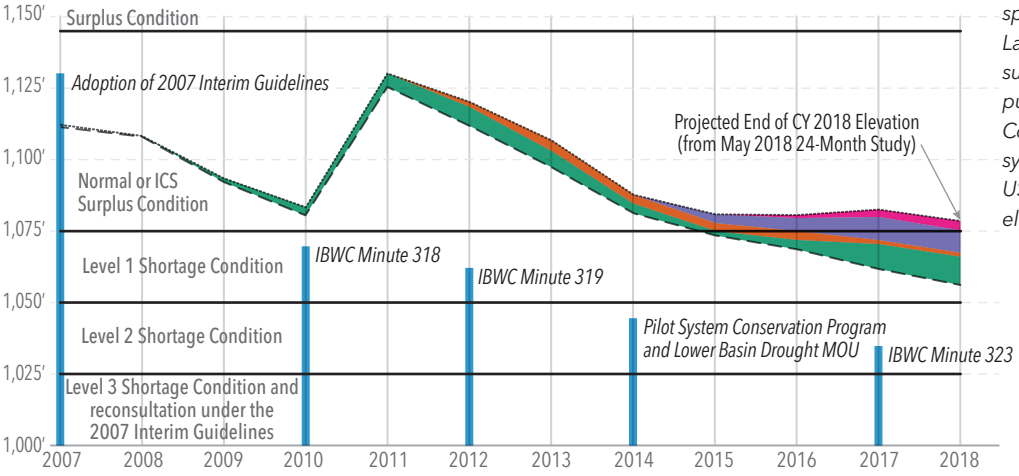
processes at a sub-seasonal to seasonal timescale (called the S2S timescale by atmospheric scientists). The S2S timescale – two weeks to one to two years – is sometimes referred to as the bridge between weather and climate, as it links short-term weather conditions with longer-term processes. Although the ability to make skillful operational weather forecasts of precipitation (out to two weeks in advance)

Below left: *Montecito Water District's Juncal Dam and Jameson Lake prior to the December 2017 Thomas Fire, which burned most of the watershed. Subsequently, January 2018 mudslides from rain on the burned areas caused significant damage to the district's Jameson Pipeline and other water system infrastructure. The district estimated that there were nine transmission pipeline breaks, 15 distribution main breaks, 25 sheared-off fire hydrants, and approximately 290 damaged service connections, resulting in a boil water order for affected residents until the water system could be repaired and disinfected. Photo courtesy of Montecito Water District*

Below: *Montecito Mudslides. Massive debris flows in Montecito in January 2018, due to locally intense precipitation on burned areas. Photo courtesy of Mike Eliason, Santa Barbara County Fire Department*



Lake Mead End of Calendar Year Elevation

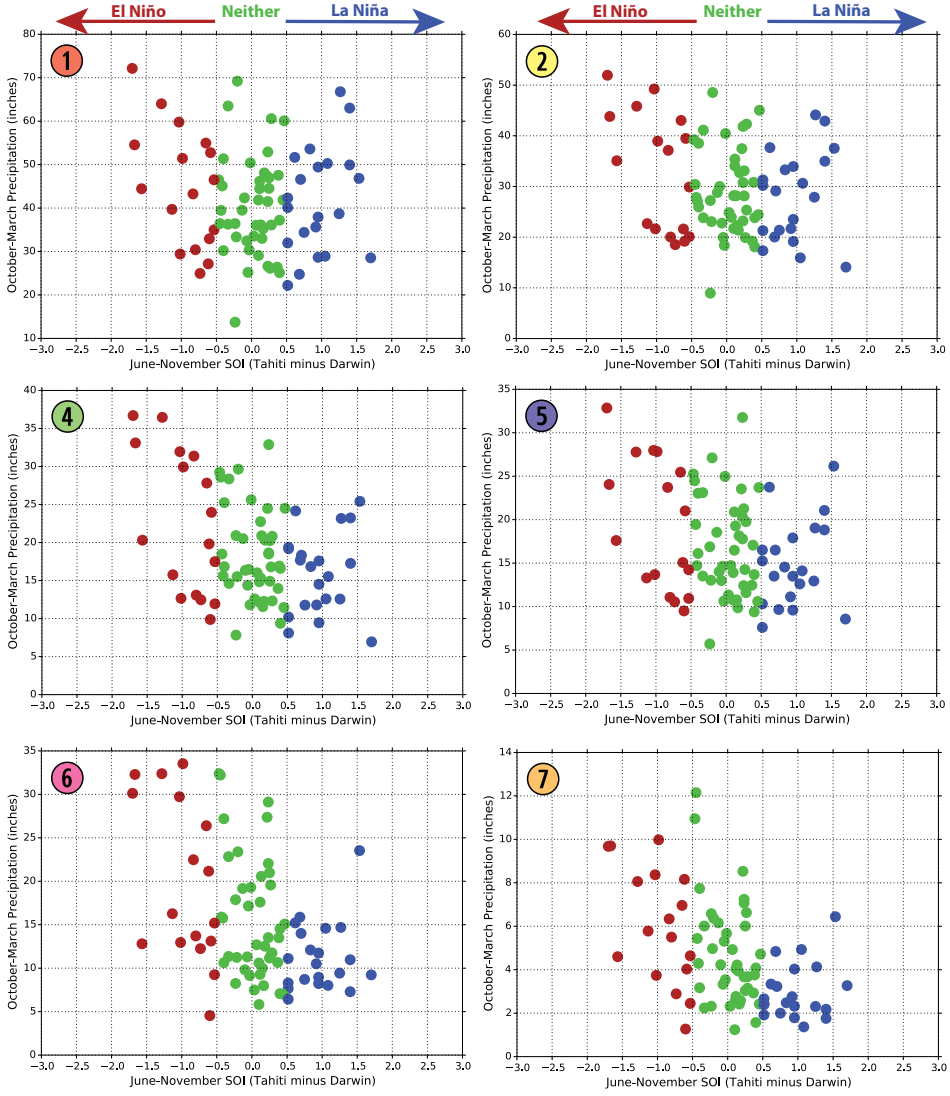


Since 2007, institutional actions have created special categories of water to be stored in Lake Mead, including intentionally created surplus water, deferred Mexican delivery water pursuant to International Boundary and Water Commission treaty minutes, and voluntary system conservation water. Figure courtesy of USBR. Projected end of calendar year 2018 elevation based on provisional data.

- U.S. ICS
- Other Voluntary Contributions
- Actual Elevation
- Mexico's Water Reserve
- System Conservation Water
- Hypothetical Elevation without Storage/Conservation Programs

ENSO and California precipitation

The high annual variability in California's annual precipitation means that every year could hold the possibility for record wet conditions, such as those of 2017, or for a return to dry conditions. In the absence of reliable predictive ability, Californians must be prepared for the possibility of extreme wet or dry conditions in any water year.



California climate divisions

SOI - Southern Oscillation Index

Data courtesy of Western Regional Climate Center

has greatly improved over the past several decades, the same cannot be said for making forecasts at the S2S timescale. The National Weather Service (NWS) Climate Prediction Center has limited ability to predict the precipitation outlook for the winter months that are so important to California's water supply.

Improving forecasts at S2S timescales is critically needed for improving efficiency of water operations. Much hope has been pinned on using the status of the El Niño-Southern Oscillation (ENSO) as an indicator of seasonal conditions, but the historical record for California shows that precipitation in most of the state has little relationship to ENSO conditions, except for a tendency in Southern California to link La Niña conditions with dryness. The inability to correctly predict seasonal precipitation in water year 2016 during one of the strongest El Niño events of record illustrates how much work remains to be done in this area.

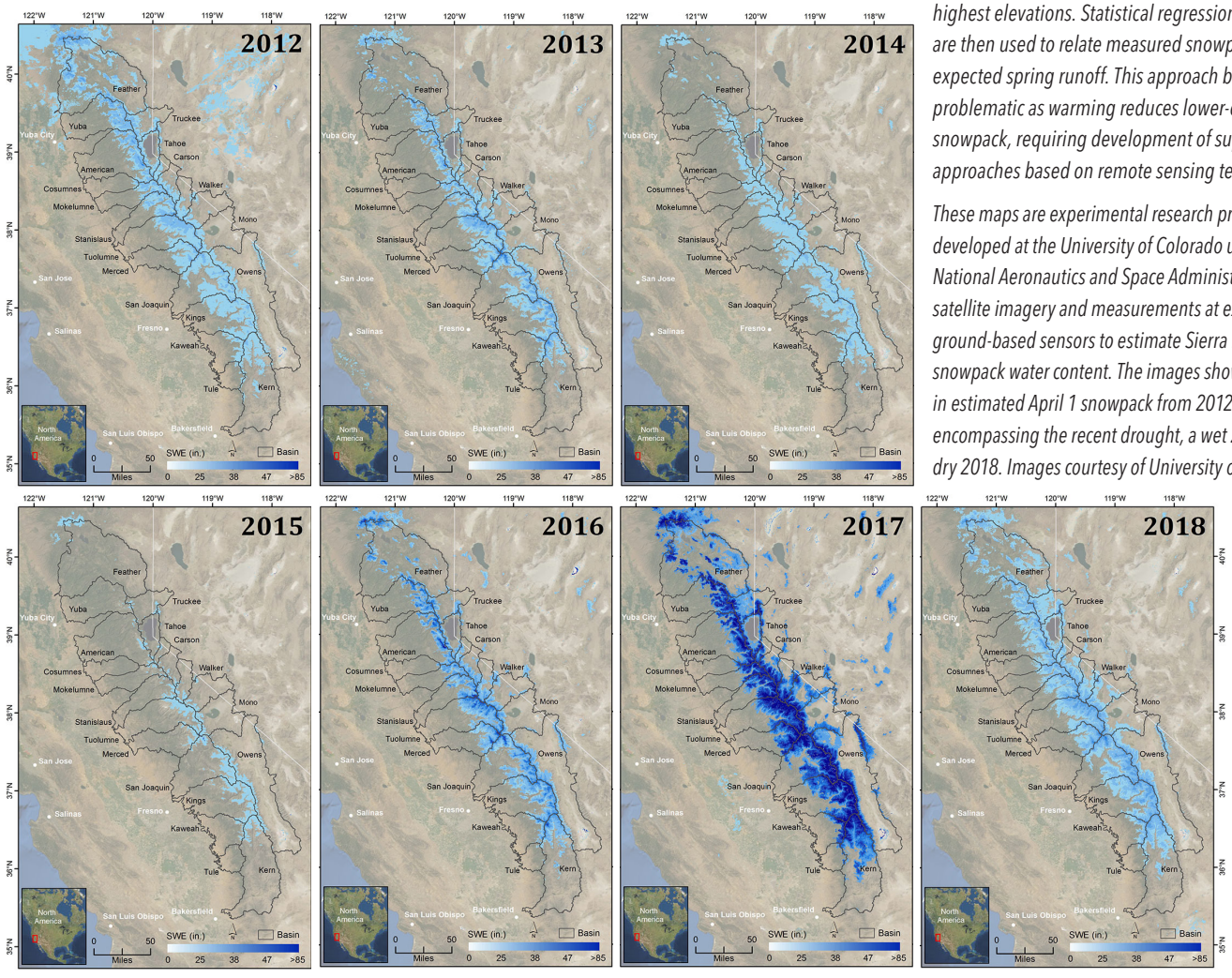
The accompanying figure shows relationships between ENSO and historically observed California precipitation at the scale of NOAA climate divisions. As illustrated in the plots, the only historically observed relationship between ENSO status and precipitation in California is for Southern California to tend toward dryness in most, but not all, La Niña years.

Snowpack, 2012 - 2018

A warming climate results in a greater amount of precipitation falling as rain rather than as snow. During the 2012-16 drought, a record low of 5 percent of average April 1 statewide snowpack was set in water year 2015, with water year 2014 tying 1977 for second place at 25 percent of average. These changing conditions affect the ability to monitor snowpack and forecast snowpack runoff.

Agencies have historically measured snowpack by taking core samples or measuring the weight of snow above a sensor (snow pillow). This approach is biased toward sampling lower-elevation sites due to the practical difficulties of access to sites at the highest elevations. Statistical regression equations are then used to relate measured snowpack to expected spring runoff. This approach becomes problematic as warming reduces lower-elevation snowpack, requiring development of supplemental approaches based on remote sensing technologies.

These maps are experimental research products developed at the University of Colorado using National Aeronautics and Space Administration satellite imagery and measurements at existing ground-based sensors to estimate Sierra Nevada snowpack water content. The images show variation in estimated April 1 snowpack from 2012-18, encompassing the recent drought, a wet 2017, and a dry 2018. Images courtesy of University of Colorado.



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